Specification

This document shall define the top-level specification for a Double Focussing Monochromator for use in instrumentation at the NIST reactor (NBSR). The document shall become effective only if all owners whose names shall appear below have signed it. Changes to the signed document shall only be initiated by one of the owners, or their replacements, at which time a new document including the proposed revision shall be prepared. Changes shall become effective only after all parties shall have signed the new document. The old document shall remain part of the record.

0 Control Data

0.1. Project Name

Doubly Focusing Monochromator

0.2. Revision (-, A, B ….. AA, BB, …. *etc*.)

Revision B

0.3. Date

July 30, 1999.

0.4. Owners

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1. Definitions for the purpose of this document

1.1. Monochromator Crystal Unit (MCU)

A square coupon of Pyrolytic Graphite, dimensions $2.0(1) \times 2.0(1) \times 0.20(2)$ cm^3.

1.2. Bragg Condition.

An optical arrangement such that a neutron beam with wavelength l impinges on and leaves an MCU with angle of incidence q. The angle q is defined with respect to the crystal surface. The total scattering angle for the neutrons is therefore $2q$. In this arrangement the following mathematical relationship is maintained.

$$2\,d\,\sin q = n\ l$$

with n an integer (in this case n = 1) and d the atomic distance in the crystal in the direction normal to the MCU (d=0.33542 nm for Pyrolytic graphite).

1.3. Neutron Source (NS)

A surface from which neutrons of all wavelengths leave in all directions. For this purpose you can consider this to be a point source.

1.4. Neutron source distance (NSD)

The distance between the NS and an MCU.

1.5. Sample Position (SP)

A position on a line making an angle $2q$ with the connection line between the NS and the MCU in such a way that the Bragg condition is fulfilled.

1.6. Sample distance (SD).

The distance between an MCU and the SP.

1.7. Rowland Circle

A circle that goes through the NS an MCU and the SP.

1.8. Horizontal fixed wavelength Focussing.

A horizontal array of MCU's arranged in such a way that the line that connects them is tangent to the Rowland circle. At the same time every MCU is oriented in such a way that they all satisfy the same Bragg Condition (hence the fixed wavelength).

1.9. Horizontal non-fixed wavelength Focussing.

This is defined as every form of horizontal focussing that is not fixed wavelength focussing. We therefore introduce the tangentiality angle j The angle j is defined as the angle between the actual orientation of the line that connects the horizontal MCU array and the tangent to the Rowland Circle. Note that when $j = 0$, one has the situation described in 1.8. Also note that if $j \neq 0$, all elements of a horizontal MCU array satisfy a slightly different Bragg Condition, hence: non fixed wavelength focussing.

1.10. Vertical Focussing

A vertical array of MCU's arranged in such a way that they form a cylindrical lens that creates an image of the NS on the SP. The radius of curvature is given by fundamental optics equations:

$$\frac{2\sin q}{R} = \frac{1}{\mathrm{NSD}} + \frac{1}{\mathrm{SD}}$$

1.11. Double Focussing

An arrangement of a two-dimensional array of MCU's combining 1.8. or 1.9. with 1.10. This arrangement is characterized by two distinct radii, both functions of $2q$.

1.12. Test Day

A 24 hr period during which testing occurs.

1.13. Test Year

A 365 day period during which the reactor is running 80% of the time; therefore a test year represents 292 days of run time.

2. Deliverables for this project by Developers

2.1. An instrument that allows double focussing of neutrons over a range of $2q$ values and thus a range of Rowland circle radii (1.8. and 1.9.) and vertical focussing radii (1.10.).

2.1.1. $2q$ - range: $35° < 2q < 120°$

2.1.2. NSD: 5000 mm

2.1.3. SD: 2200 mm

2.2. System for collective simultaneous remote control of the radius of curvature of all vertical arrays. Each vertical array consists of 15 MCU's. This allows for the collective optimization of the radius of curvature, per 1.10.. Limits on radius of curvature are 0.9 m < R < 10 m. Total domain shall be traveled in 3 seconds or less. The average number of focus events per test day being 40 with each event spanning the full range of travel.

2.3. System for remote control of the orientation of 21 vertical MCU arrays; each vertical array individually. This allows for the individual optimization of a vertical array per 1.8., 1.9. and 1.10.. Speed of rotation shall be 2 rpm or faster. The average number of reorientations for a vertical array, per test day, being 60 with each reorientation consisting of a 1.5° rotation.

2.4. System for the collective translation of the assembly of 2.2. and 2.3 in the direction perpendicular to the two dimensional array of MCU's. The range shall be 4 cm approximately centered on the unbent surface of the vertical MCU arrays. The whole range shall be traveled in no more than 20 sec. The average number of translation events shall be 40 per test day, each event being 3 mm.

2.5. System for the collective remote control rotation of the assembly of 2.2, 2.3, and 2.4 around the central position of the latter. This allows for the choice of degree of tangentiality as pointed out in 1.9.. This device defines the angle j. Speed of rotation shall be of order 1 degree per second. The average number of rotation events per test day will be 40, each event being 1° on average.

2.6. Permanent (three-point, set-screws etc.) adjustment of degrees of freedom that are not covered by remote control.

2.7. Remote control of two-dimensional focussing, through external input of j, 2q, NSD, and SD.

2.8. Procedure and set-up for the testing of the device, using a diffuse light source and shiny mirrors instead of monochromator crystals. Tests shall prove that after addition of all tolerances no MCU shall be more than 0.15° away from their theoretical orientation. The reproducibility of the orientation shall be 0.03° or better after 5000 motor operations.

2.9. An interface with an external computer for all remote control operations defined above as well as a procedure for the initiators to approve of such shall be proposed.

2.10. Mean time to hard failure (MTHF) – that requiring instrument removal – shall be no less than 2 yrs. Mean time to soft failure (MTSF) – that requiring re-homing of the instrument – shall be no less than 2 months. Mean time to alignment failure (MTAF) – that requiring neutron realignment – shall be no less than 6 months.

3. Limitations

3.1. Materials and parts

3.1.1. Where required, radiation hardened components shall be procured. These components must be spec'd to satisfy the instrument MTF (2.10.) based on the local radiation environment of 100 rad/hr.

3.1.2. Where possible cold rolled 1100 type aluminum alloys shall be used. Where strength is of the essence 6061 aluminum shall be used.

3.1.3. Barrier shielding made from 2 mm thick boron-10-aluminum sheet (NIST) shall cover all parts of the device outside of the MCU array.

3.1.4. In the exposed area minimize material other than Pyrolitic Graphite. Screws, strips shall be made of Aluminum alloys. The quantity of MCU array support material shall be minimized in particular.

3.2. Living space and handling.

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3.2.1. The device shall fit into a cylindrical volume of diameter 52 cm and height *65 cm* (?) when the center of the reflecting graphite surface lies on the cylinder axis. The distance between the beam center and the lower mounting surface shall not exceed 45 cm.

3.2.2. Attaching and detaching the device shall be fast and easy with access from above only (the device will live at the bottom of a 60 cm diameter and approximately 1 m deep well).

3.2.3. Disassembly of the device shall be made as easy as possible.

3.4. Software and Electronics

3.4.1. All communications from and to outside the system shall be compatible with a communication standard on which initiators and developers shall agree.

3.4.2. There shall be software provisions to avoid collisions between vertical MCU arrays.

3.4.3. Provision must be in place to log and maintain position information at the completion of each move.

3.4.4. Amount and complexity of electrical connectors shall be minimized.

4. Additional Design considerations

4.1. Some clearance between the MCU's shall be allowed. The clearance shall be minimized considering the movements of individual crystals.

4.2. MCU dimensions: $2.0(1) \times 2.0(1)$ cm $\times$ 0.20(2) cm.

4.3. In the configuration where the horizontal arrays are tangent to the Rowland Circle, any irradiated frame support shall have mass no greater than 200 g (aluminum as per 3.1.2.).

4.4 All vertical MCU arrays shall have equal radius of curvature at all times. To avoid over tolerancing the vertical arrays, there shall be a permanent one-time manual adjustment on the individual vertical arrays.

4.5 There shall be a uniform mechanical interface between the rotation stage, the translation stage, and the monochromator functionally equivalent to LEGO. Furthermore there shall be a mechanical interface on the top of the monochromator equal to that on the top of the rotation and translation stages.

4.6 If the current concept using Pyrolytic Graphite MCU's is successful, it shall also be applied to MCU's made of Copper single crystals with individual dimensions of $25 \times 25 \times 8\ mm^3$. Such MCU's are considerably heavier than the Pyrolytic Graphite ones. The assembly shall consist of a yet undetermined number of vertical arrays that shall each be 8 MCU's high (i.e. 8″ high). This future development shall be considered when developing the current design.